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1969

Geology and Land Use in Eastern Washington County, Pennsylvania

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Geology and Land Use in Eastern Washington County, Pennsylvania

**by B. H. Kent, S. P. Schweinfurth,
and J. B. Roen**

Geologists, U. S. Geological Survey

**Prepared in cooperation between the United
States Geological Survey and the Pennsylvania
Geological Survey**

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PREFACE

This report describes some aspects of the composition, structure, and present condition of the bedrock in eastern Washington County that affect land uses and land-use planning. It discusses briefly how the rocks and rock layers react to natural forces and processes that continue to act upon them, to form contact springs and landslides, and to create engineering and construction problems.

The "lithologic" maps that accompany this report show the general distribution, thickness, and variation of each of the principal coal beds and sandstone and limestone units which are at or near the ground surface within the mapped area. "Generalized lithologic columns" show the vertical sequence, respective stratigraphic positions, and names of these principal coal beds and other rock units which are discussed individually in the text.

On the lithologic maps, the structure of the bedrock is outlined by "structure contours" drawn on the base of the Pittsburgh coal bed. Data such as the amount of dip of a given rock layer, the depth to a rock layer at a given locality, and probable directions on ground-water movement, can be obtained by means of simple measurements and calculations outlined in the report.

The report also provides more specific information, such as analytical and laboratory-test data on representative samples of sandstone, limestone, coal, mudstone, claystone, and landslide material, and includes calculated reserves of Waynesburg coal within the mapped area. An index map showing the status of recent lithologic and geologic mapping in southwestern Pennsylvania is included.

Washington County borders the Pittsburgh metropolitan area, one of the major population and industrial centers in the United States. Within the next 10 years, much of what is now rural farmland within the county probably will be converted and subdivided to meet the needs of increasing population and industrial expansion. There appears to be no limit to this projected growth but there is a definite limit to the amount of land available, and land uses and land-use problems will therefore become increasingly critical. Rocks and geologic conditions may be either the cause of such problems or the means of resolving them, and geologic studies are most effective during the early stages of land-use planning, before land is committed and construction begins.

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GEOLOGY AND LAND USE IN EASTERN WASHINGTON COUNTY, PENNSYLVANIA

by

B. H. Kent, S. P. Schweinfurth, and J. B. Roen

U.S. Geological Survey*

ABSTRACT

This brief report and the lithologic maps that accompany it call attention to some aspects of the geology of an eastern part of Washington County, Pennsylvania, that affect land utilization. It is not intended to be comprehensive. No comments made herein are intended as specific recommendations, except in the sense that the relation between a specific land use and the specific locality selected will require additional and much more detailed geologic and engineering study. Background geologic information provided here concerns the bedrock, the structure of it, jointing, general descriptions of rock types involved, map portrayal of the areal distribution and thickness of the principal sandstone, limestone, and coal beds, and brief discussions of such topics as contact springs and landslides. Additional information concerning uses of structure contours and representative analytical data on the composition and properties of various rock types are provided in the appendix.

INTRODUCTION

A substantial portion of Washington County, Pennsylvania, is in the process of changeover from rural farming to suburban adjuncts of the metropolitan area of Pittsburgh lying to the north. The population is growing rapidly; new subdivisions are being built, new industries are being established and others are being relocated, and more roads are under construction or planned.

But the land on which this development must take place was not especially created for any of these land uses. The bedrock has been there many millions of years, and the characteristic reactions of the bedrock to the natural forces and processes that continue to act upon it have long since been established.

We are concerned with modern, complex problems such as water supply, seepage, waste disposal, water pollution, landslides, and engineering construction. Rocks and geologic conditions may be either the cause of such problems or the means of resolving them, and geology can be most effective in the early stages of land-use planning and development

* Publication authorized by the Director, U.S. Geological Survey.

when some of these problems can be anticipated and avoided; geologic problems that occur unexpectedly during later stages of commitment and construction are usually much more costly and difficult to resolve. Wherever and whenever there is some degree of flexibility in planning it is much better to try to fit the uses required to the framework of the land available, rather than to make the land fit the uses. And when compromises must be made, they should be based on the geology.

LITHOLOGIC MAPS

The lithologic quadrangle maps are based on extensive field work supplemented by core log and mine map information.

These data were collected primarily for use in preparing geologic quadrangle maps (Berryhill and Schweinfurth, 1964; Kent, 1967; Schweinfurth, 1967; and Roen, Kent, and Schweinfurth, 1968). These maps are part of a series of geologic maps of selected quadrangles in southwestern Pennsylvania, which are one product of a current cooperative research program of the Pennsylvania Geological Survey and the U.S. Geological Survey. (See Figure 1)

However, these general geologic maps were prepared primarily for scientific purposes. They do not show features such as individual beds of coal, sandstone, and limestone, and knowledge of such features is needed for land use and engineering planning. A "lithologic" map is the most convenient way to present this kind of information.

The primary purpose of the lithologic maps is to show the distribution, thickness, and variation of each of the principal coal, limestone, and sandstone units which are at or near the ground surface in the area. All units of the same rock type are shown in the same color or pattern. Portions left blank on the lithologic maps represent areas in which mixtures of mudstone and siltstone predominate. (Rock terms are defined and discussed in the section entitled "Rock Types.")

Coal beds are shown as lines; thicknesses of coal are indicated by a number code, and the "X"s at intervals along the lines depicting these coal beds indicate the approximate location where a change in coal thickness occurs; abbreviations of the names of the ten best known coal beds are shown along the coded lines.

The coal beds provide a correlation between the lithologic maps and the geologic maps when the generalized lithologic column (Plates) for the lithologic maps is compared with the generalized lithologic column that accompanies each of the geologic maps. As an additional guide to making correlations between the two types of maps, the geologic names of the members and formations and the symbols for them, are shown along the left side of the generalized lithologic column for the lithologic maps.

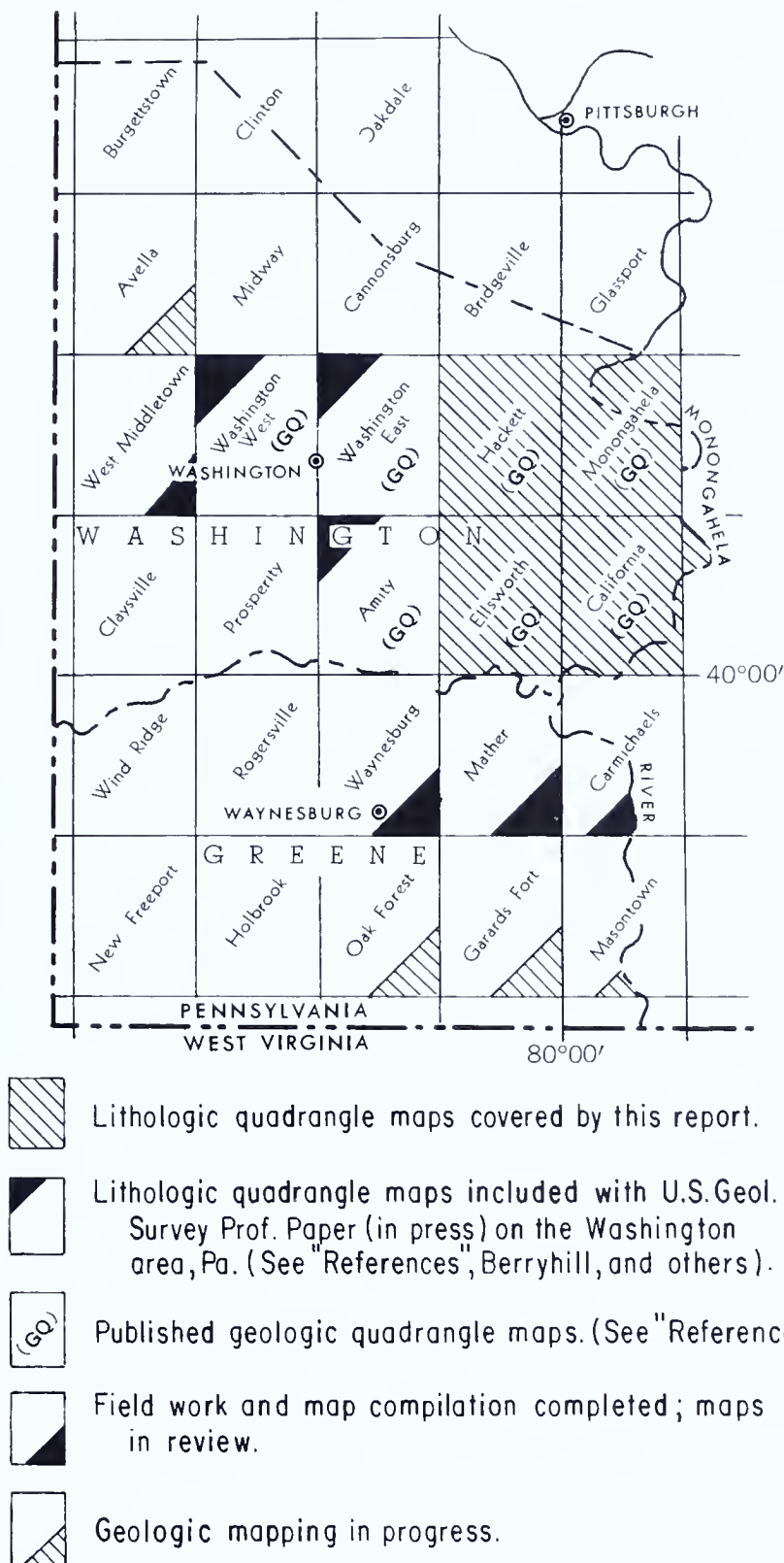


Figure 1. Index map of 7½' quadrangles in southwestern Pennsylvania, showing status of geologic mapping (1:24,000 scale) in cooperation between the U. S. Geological Survey and the Commonwealth of Pennsylvania, Bureau of Topographic and Geologic Survey, (Status as of July 1, 1968).

The lithologic maps are supplements to the geologic maps and should be used with them. These maps, in combination with background geologic information outlined herein, could be used for such planning purposes as interpreting the general foundation and excavation conditions to be expected at various localities; locating favorable construction sites; estimating drilling depths and excavation costs; determining the depth to a particular rock layer; locating rocks most suitable for fill; estimating water storage potential; estimating commodity resources; and locating landslide and areas or zones susceptible to landsliding.

BEDROCK

As used herein, "bedrock" refers collectively to the layers of consolidated, undisturbed rock in place either at the surface or beneath deposits of gravel, sand, or soil.

Within the mapped area, the maximum thickness of the bedrock section above the Pittsburgh coal is about 900 feet (in the southwestern corner of the Ellsworth quadrangle). The bedrock section consists of alternating layers of sandstone, siltstone, and mudstone, limestone, claystone, under clay, coal, and carbonaceous shale. (See "Rock Types")

The coal beds, even though they rarely exceed 6 feet in thickness, are the most persistent and distinctive rock units; many of them can be identified and traced throughout southwestern Pennsylvania. Coal or carbonaceous layers occur at 20- to 80-foot intervals throughout the total bedrock section, and within the mapped area the thicknesses of the intervals between coal beds are remarkably consistent.

The succession of rock units within a given interval between coal or carbonaceous layers is generally characteristic; but the succession of rock types and the relative proportions of rock types vary from one interval to another, and even from one place to another within the same sequence—for example, a sandstone or limestone unit within a given interval may be thick at one locality and very thin or absent at another.

The bulk of the bedrock section in the mapped area consists of mudstone units containing thin beds of siltstone and sandstone; however, some of the limestone and sandstone units in the intervals between coal beds are locally as much as 60 feet thick. The limestone units generally are more persistent and consistent in thickness than the sandstone units which show abrupt and pronounced variations in thickness. However, the many sandstone units (and also the limestone units) are all so monotonously similar that in most places identification depends on establishing the position of a sandstone or limestone unit with respect to overlying or underlying identifiable coal beds.

The structure, or attitudes, of the rock layers that make up the bedrock section, and the joints or fractures that cut through them, are briefly described in the following paragraphs.

STRUCTURE OF THE BEDROCK

Rock layers in southwestern Pennsylvania have been gently folded into broad anticlines (arches) and synclines (troughs), the axes of which trend southwest. Rock layers that form the flanks of these folds dip away from the axes of anticlines (or toward the axes of synclines); thus the predominant directions of dip are northwest and southeast. All the folded rock layers, however, have been tilted southwestward.

The most convenient and useful way to show the combined effects of this folding and tilting is by means of *structure contours*, in which a particular surface is selected, such as the base or the top of a particular rock layer or unit, and the overall configuration (*structure*) of this surface is then depicted by lines (*contours*) that connect points of equal elevation on this surface. The method is very similar to that of drawing topographic maps, in which contours are used to show the shape of the ground surface, whereas a structure contour map uses contours to show the shape of the surface of a particular rock layer even though it may be buried beneath the ground surface. (Data for preparing structure contour maps are obtained from core logs, mine maps, and surface information.) The *contour interval* is the vertical distance between two adjacent contours; on the accompanying lithologic maps, both the topographic contour interval and the structure contour interval are 20 feet.

The structure contours shown on the lithologic maps are drawn at 20-foot intervals on the base of the Pittsburgh coal bed. The contour pattern shows the configuration of this surface, and contour values represent elevations above sea level. Contours and structural axes outline and position the major folds, which trend southwest across the mapped area. The contour pattern also indicates that the folded surface (e.g., the base of the Pittsburgh coal) is tilted southwestward; this regional tilt is about 1° (92 ft per mile).

All rock layers above the base of the Pittsburgh coal bed are virtually parallel to this contoured surface. Structure contours are lines of equal elevation; therefore, the direction of maximum dip of rock layers is at right angles to the contour lines. The actual amount of dip of any given rock layer can be approximated closely by (a) selecting a structure contour and measuring off a mile (or some portion of it) at right angles from it, at map scale; (b) counting the number of different contour intervals that cross this segment; and (c) multiplying this number by the contour interval (20 ft), to obtain the amount of dip in terms of feet per mile.

On the lithologic maps, the overall spacing of structure contours indicates that the average dip of rock layers within the mapped area is about 1° (92 ft per mile). Dips are steeper in areas where the contours are more closely spaced, but they rarely exceed 5° . Dips as gentle as 1° – 2° , though not easily detected in a single outcrop, will strongly influence the direction of movement of ground water, and over a distance of several miles

such gentle dips have a pronounced effect on the position of a given rock layer with respect to ground elevations and surface exposure. For example, the Pittsburgh coal bed is a surface exposure (at about 1,000 ft elevation) near the town of Hackett, but lies about 600 feet beneath the valley floor in the extreme southwest corner of the Ellsworth quadrangle. Therefore, in approaching land-use problems such as water pollution or water availability, in which even a slight change of dip could be significant, calculation of the dip from the structure contours may provide vital information that might otherwise be overlooked.

At any locality within the mapped area the approximate depth to the base of the Pittsburgh coal bed can, of course, be obtained by subtracting the elevation of the structure contour from the elevation of the topographic contour at the same locality. As all rock layers above the Pittsburgh coal bed are virtually parallel to it, a simple calculation, based on the average distance from the base of the Pittsburgh coal bed to a given rock layer above it, will provide the approximate depth to that rock layer in a given locality. Average distances (or intervals) between rock units can be obtained from the lithologic column. Examples of the calculations necessary are provided in Figure 2.

Structure contours on the base of the Pittsburgh coal bed do not necessarily indicate that the Pittsburgh coal bed itself is still present in any given locality. In fact, the Pittsburgh coal bed has been mined out in most of the area covered by the Monongahela, California, and Ellsworth quadrangles, and it is now being mined extensively in the Hackett quadrangle. Determinations of where this coal is still present, and where some of it has been left in "mined out" areas, are critical factors in many land-use or engineering problems. Up-to-date information on the status and progress of coal mining within the mapped area is shown on detailed mine maps which are on file in the Department of Mines and Mineral Industries, Commonwealth of Pennsylvania, Harrisburg, Pennsylvania, 17120. Current mine maps are also on file at the Bureau of Bituminous Mine Subsidence and Land Conservation, 203 S. Washington, Rd., McMurray, Pennsylvania, 15317.

On geologic quadrangle maps, such as the geologic map of the Ellsworth quadrangle (Berryhill and Schweinfurth, 1964), structure contours on the base of the Pittsburgh coal bed are broken by red crosses in areas where the Pittsburgh coal is known to have been mined out. However, it is emphasized that this information is much too generalized for many land-use planning or engineering purposes.

JOINTING IN THE BEDROCK

Bedrock in all parts of the area is cracked and broken by continuous well-defined fractures that are more or less perpendicular to the rock layers. Such fractures are known as joints.

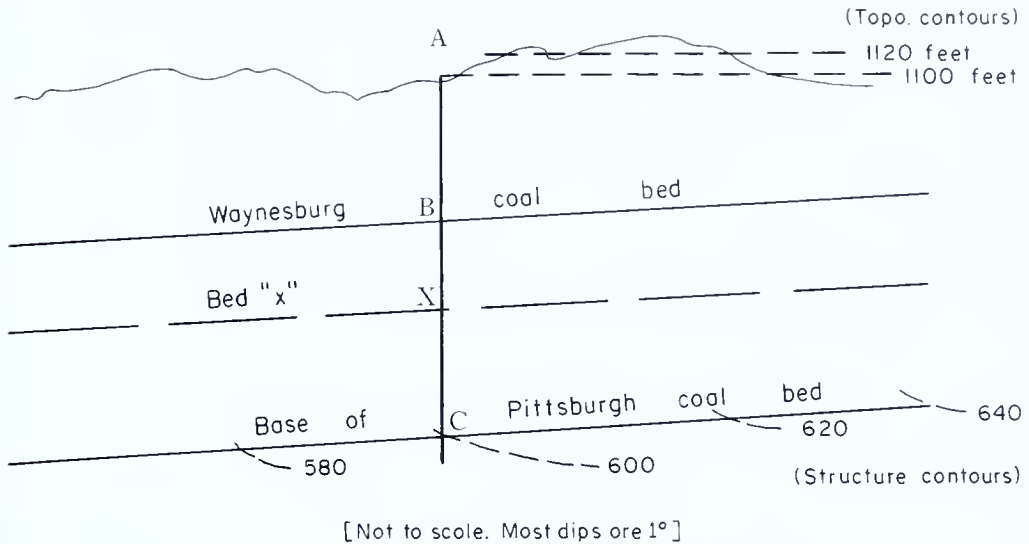


Figure 2. Use of structure cantours and topographic cantours to determine the approximate depth to a given rock layer, when all rock layers above the structure-contoured surface are virtually parallel to it. Examples: (1) depth to Waynesburg coal bed, below ground point A, and (2) depth to bed "X," below ground point A.

(1) Depth to Waynesburg coal below point A:

Elevation of point A = 1,100 feet (from topographic cantours)

Elevation of point C = 600 feet (from structure cantours)

Interval AC = 1,100 feet - 600 feet = 500 feet

Interval BC = 330 feet (as measured on the lithologic column)

Depth (AB) = interval AC (500 feet) - interval BC (330 feet) = 170 feet = depth to Waynesburg coal below point A

(2) Depth to bed "X" below point A:

Interval AC (1100 feet - 600 feet) = 500 feet

Measure interval XC on the lithologic column

Depth (AX) = interval AC - interval XC = depth to bed "X" below point A

Joints create zones or planes of weakness in bedrock, thereby reducing the inherent strength of the rock layers; passageways are created, along which the rock is most susceptible to attack by erosional processes such as frost action and percolating water, and rock layers tend to break into rectangular blocks. However, joints are also beneficial; the passageways through which water can move rather freely may cause a significant increase in the effective permeability and water-bearing capacity of the rock layer, and the tendency of the rock layers to break into rectangular blocks permits the rock to be quarried or excavated more easily.

Joints tend to be most prevalent and largest in the bedrock at or near the ground surface and near the crests of anticlinal structures (because of greater tension along the crests). Joints generally become less prevalent and smaller from the ground surface downward. One significant consequence is that near-surface, relatively impermeable "tight" sandstone and limestone layers, which owe much of their permeability and water-bearing capacities to the presence of well-developed joints, may

lose these capabilities below depths of 100 feet or so. Laboratory tests determine the degree of porosity and permeability of a sample of rock (Table 1), but such tests do not reflect any effective increase in the actual water-bearing capability of the rock *unit*, resulting from joints whose size or spacing is such that they are not present in the hand-sized rock sample. However, this situation should in no way deter testing programs nor reflect on their value. If a representative sample of rock is tested and found to be relatively impermeable, any significant water-bearing capability the rock unit may have is very likely related to the presence of well-developed joints. In such a circumstance, both the position of the rock unit with respect to the ground surface and the locality of the unit with respect to anticlinal structures should be considered in assessing the potential water-bearing capability of a particular rock unit, at any given locality.

Joints most commonly occur as sets of more or less parallel fractures which have a definite trend or orientation. Two sets of joints intersecting at right angles are known as a "conjugate" set. Several conjugate sets are present in the mapped area; the most prevalent and best developed set trends N. 25° E. and N. 65° W.

ROCK TYPES

Specific rock types that are present in the mapped area include sandstone, limestone, coal, mudstone, and claystone. Each of these rock types is described briefly and the distributions of the more significant units of each rock type are discussed and related to land uses. The stratigraphic positions of the more prominent rock units and the average intervals between rock units are shown in the generalized lithologic columns (Plates) wherein the sandstone units are identified by letter code, the limestone units are identified by number code, and the more prominent coal beds are identified by abbreviations of their names. The terms "layer" (of rock) and "bed" (of rock) are used herein synonymously; a rock "unit" consists of one or more layers of the same type of rock; a layer (or bed) of rock is commonly less than 6 feet thick, whereas a rock unit may be as much as 60 feet thick.

Representative analytical data on rock composition, porosity and permeability, and other physical properties are included in the tables.

SANDSTONE

Description

The sandstone is a rough, grainy rock, occurring as sharply defined layers and units which are scattered throughout the bedrock section. Each sandstone layer is a consolidated mass of mineral grains and frag-

ments, bonded by clay minerals and cementing material. All of the sandstone is remarkably similar in appearance, composition, and grain size. Fresh sandstone is medium gray in color and weathered sandstone is olive gray with some buff and yellowish coloration locally; however, the sandstone in the interval between the top of limestone 4 and the base of the Uniontown (Ut) coal bed (see the generalized lithologic columns, Plates) has a conspicuous green color, which is a distinguishing feature.

The composition of the sandstone is as follows: quartz and feldspar grains, about 80 percent; clay minerals, generally more than 10 percent; mica flakes and fragments, from 3 to 7 percent; pyrite grains, carbonized plant fragments, and miscellaneous mineral grains make up the remainder. Because of its relatively high clay mineral content, the sandstone is classified as "impure".

Grain sizes range from "very fine"-grained ($\frac{1}{8}$ - $\frac{1}{16}$ mm in diameter) to "fine"-grained ($\frac{1}{4}$ - $\frac{1}{8}$ mm), although locally some "medium"-grained ($\frac{1}{2}$ - $\frac{1}{4}$ mm) sandstone is present near the bases of the thicker sandstone units. (See Figure 3 for grain-size distributions in a representative sandstone unit, and for a table showing the grain-size classification used in this report).

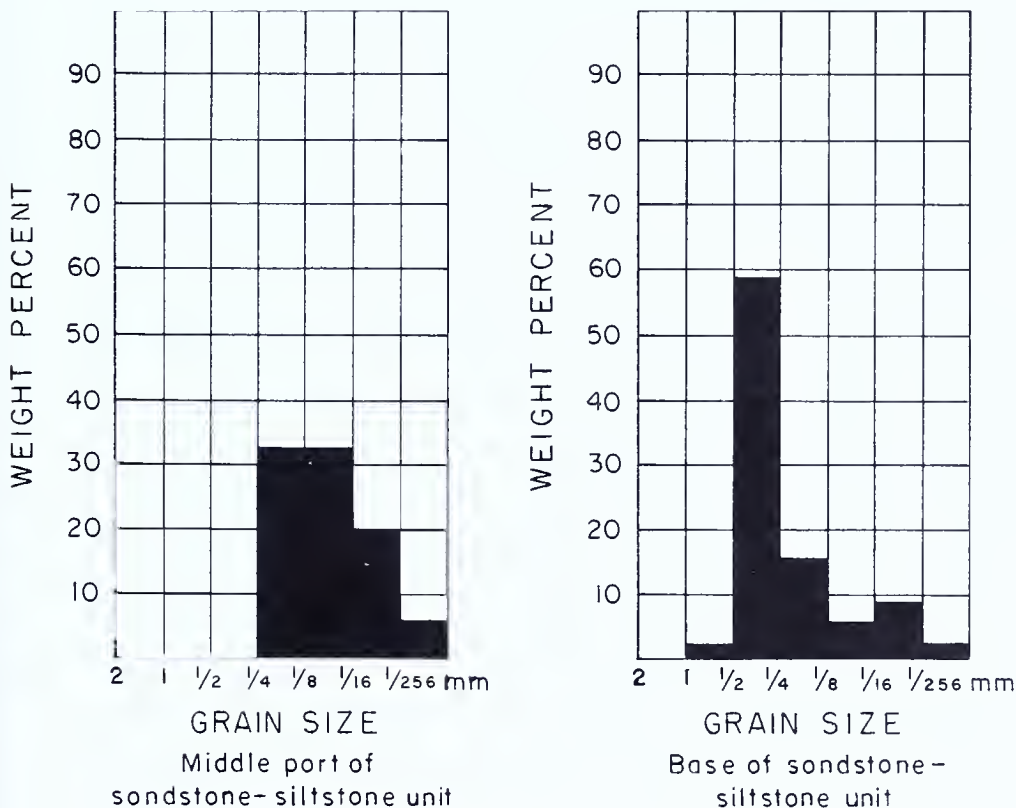


Figure 3. Vertical distribution of grain size in a typical sandstone-siltstone unit (Wentworth size classification used in this report in Krumbein and Pettijohn, 1938, table 6, p. 80).

Table 1. *Physical and hydrologic properties of representative sandstone samples**

Sandstone unit	Location	Specific gravity	Dry unit weight (gm/cm ³)	Centrifuge moisture equivalent	Total porosity	Specific yield	Permeability (gal/day/ft ²)	Compressive strength (lbs/in ²)
Sandstone C	NW $\frac{1}{4}$ Washington East quadrangle	2.68	2.35	3.6	12.3	3.8	0.001	13,800
Sandstone F	NW $\frac{1}{4}$ Washington East quadrangle	2.68	2.20	4.4	17.9	8.2	.03	11,900
Sandstone H	Central part, Amity quadrangle	2.69	2.31	3.8	14.1	5.3	.002	12,400
Sandstone J	SW $\frac{1}{4}$ Washington West quadrangle	2.68	2.28	3.4	14.9	7.1	.02	10,200

* Analysts: Compressibility strength tests by T. C. Nichols, G. S. Erickson, and J. C. Thomas, U.S. Geol. Survey; hydrologic properties and specific gravity tests by R. P. Moston and A. H. Ludwig, U.S. Geol. Survey

The sandstone, because of its relatively high clay mineral content and its fine-grained nature, has relatively low permeability (Table 1).

Individual layers of sandstone are commonly less than 3 feet thick; however, any layer thicker than 1 foot is described as being "massive". Sandstone units, composed of massive sandstone layers which vary considerably in thickness, are usually lenticular and may also be described as (sandstone) "bodies".

Distribution

The vertical distribution of sandstone and the stratigraphic positions of the thicker sandstone units are shown on the generalized lithologic columns (Plates); the areal (or lateral) distribution and thickness variations of these thicker units are shown on the lithologic maps.

It is emphasized that even the thickest sandstone units (such as sandstones C, F, and H) are by no means continuous throughout the area; a sandstone unit that is very thick at one locality may be much thinner—and perhaps absent—at localities close by. However, in general, all sandstone units become somewhat thicker and more continuous eastward and southward from the crest of the Amity anticline in the Hackett quadrangle.

The thickest units of massive sandstone occur in the form of narrow elongate bodies, commonly 20 to 60 feet thick and 200 to 3,000 feet wide, which follow sinuous anastomosing trends across the area. Such bodies are thought to represent fill of ancient channels previously cut into

older, underlying rock layers. These channels were part of the ancient landscapes, and are unrelated to present-day topography; they are, in fact, buried beneath the present ground surface and may cut across the present valleys.

The bases of these ancient bodies of massive sandstone are very irregular. Usually, the massive units of sandstone H and C rest directly upon the underlying Waynesburg and Pittsburgh coals, respectively, and at some localities they cut into the coal beds. Laterally and away from such trends of channel-fill sandstone, however, these sandstone bodies thin abruptly.

Sheetlike sandstone bodies, generally less than 10 feet thick but much more extensive than the channel-fill sandstone bodies, are found between the channel-fill sandstone bodies. These more common occurrences of sandstone probably resulted from periodic overflow and lateral spreading of sand from the channel-fill phases. Sheetlike bodies of sandstone H and C may be some distance (up to 30 feet) above the underlying coals, and, generally, the intervals between the tops of the coal beds and the bases of the first sheetlike sandstones above them are filled with mudstone and siltstone.

Although beds or units of thick sandstone occur throughout the bedrock section, certain intervals in the bedrock column are characterized by a relatively high content of sandstone. In ascending order these intervals are: (1) the 160-foot section immediately below the Pittsburgh (P) coal bed; (2) the 130-foot section from the Pittsburgh coal bed up to the base of limestone 4; and (3) the 230-foot section from the Uniontown (Ut) coal bed up to the Washington (W) coal bed.

Sandstone and Land Use

From the standpoint of land use, the 230-foot section of bedrock from the Uniontown coal bed up to the Washington coal bed is perhaps the most significant. Throughout much of the mapped area—and particularly in the areas between major streams—this section of bedrock is at or near the ground surface. (The outcrop area is best seen on the geologic quadrangle maps—GQ series where it is shown in shades of purple.) The base of this section is some 260 feet above the Pittsburgh coal bed. Hillside slopes in the topography formed in this bedrock section apparently are not susceptible to landsliding for the lithologic and geologic maps show a notable scarcity of landslides associated with this bedrock. Also, the hillside slopes are generally less than 20 percent ($11^{\circ} 19'$), whereas slopes formed in bedrock sections above and below are generally greater than 20 percent. Locally, however, construction and landslide problems may occur in localities where limestone units are associated with the Waynesburg A (Wa) coal bed.

Sandstone F is notably absent in the northwestern part of the Hackett quadrangle. There, the normal stratigraphic position of this sandstone is occupied instead by unusually thick units of limestone 6.

Locally, in the north-central part of the Hackett quadrangle, in crestral areas of the Amity anticline, and in the border area between the Monongahela and California quadrangles, sandstone H is virtually absent. In its place are mudstone and thin interbeds of siltstone. Sandstone H is the Waynesburg Sandstone of Piper (1933).

As mentioned earlier, the overall sandstone content of the total section of bedrock increases from the southeast flank of the Amity anticline toward the east and south, and individual sandstone units tend to become thicker and more continuous. However, it is emphasized that the distribution patterns of sandstone bodies are quite complex, and for this reason determinations of the location and thickness of a sandstone body at any given locality will require additional and more detailed geologic investigations and drilling.

Sandstone as a Construction Material

Various sandstone units have been quarried in the past for building stone and more recently for road metal in connection with road construction such as the new Interstate 70 Highway. But, in general, the clay content of the sandstone causes it to break down rather rapidly and it is, therefore, not of any significant regional value as a construction material. However, the sandstone in the more massive bodies tends to be harder, coarser, and more durable; such sandstone may be used locally, in the future, for road construction.

Sandstone that has not been exposed to weathering may contain relatively large amounts of pyrite (on the order of 0.3 to 1.6 percent by weight), and when this sandstone is excavated a significant amount of sulfuric acid may be produced by the subsequent weathering process. This acid stains concrete and may weaken—and even disrupt—foundation structures. For these reasons, evaluations of construction sites at which sandstone would be exposed should include testing for the amount of pyrite the sandstone contains.

Water-bearing Sandstone

Many of the sandstone units are known to be water bearing, and have produced water in sufficient quantity for domestic and stock use even though laboratory tests indicate the sandstone to be relatively impermeable. This anomaly is very likely due to the presence of well-developed joints which create passageways within the rock. Sandstone units D, F, and H are known to be water bearing and productive.

Sandstone D, the Sewickley Sandstone of Hickok and Moyer (1940), has recently been drilled for water at several localities within the Hackett

quadrangle, but not all wells have produced an adequate supply. This sandstone is considerably more massive in the central areas of both the Monongahela and California quadrangles, and in these areas the chances of its being more productive are somewhat improved. However, throughout the mapped area, an unusually thick (40 to 50 feet) limestone unit (limestone 4) lies directly over sandstone D; drilling through this limestone unit could be difficult and expensive.

Sandstone F, the Uniontown Sandstone of Piper (1933), is at or near the ground surface in many parts of the mapped area. This sandstone becomes more massive, somewhat cleaner, and slightly coarser grained from the crest of the Amity anticline toward the east and south. Wells recently drilled at localities in the southeastern part of the Hackett quadrangle produced sufficient quantities of water for both domestic and stock use, and water was still being discharged at contact springs along the base of this sandstone, even after long dry spells. Artificial stock ponds located just downstream from where this contact crosses drainage have been notably successful.

Sandstone H, the Waynesburg Sandstone of Piper (1933), is from 40 to 60 feet thick throughout most of the Ellsworth quadrangle. Logs of core holes in the northwestern part of the Hackett quadrangle indicate that sandstone H is as much as 47 feet thick, but that the average thickness is about 20 feet; to the east and north of this area, sandstone H thins abruptly. Along the northwest flank of the Amity anticline sandstone H is 10 to 20 feet thick, and over crestal areas of the anticline this sandstone is usually less than 10 feet thick. In the northeastern part of the Hackett quadrangle and throughout most of the Monongahela quadrangle, sandstone H has largely been removed by erosion.

Wells drilled into sandstone H that have also penetrated the underlying Waynesburg (Wb) coal bed have produced water contaminated by impurities in the coal bed; such water may not be suitable for drinking—or even for laundry use (Piper, 1933, p. 87, 146). In selecting well sites, it is worthwhile to determine the approximate depth to the Waynesburg coal bed in order to avoid penetrating it, or to seal off this coal bed if water is to be sought from sandstone bodies at greater depth.

LIMESTONE

Description

The limestone is, for the most part, a dense, hard rock, occurring as sharply defined layers and units which are scattered throughout the bed-rock section. Limestone units consist of 2 to 25 layers or beds, which range in thickness from 1 inch to more than 3 feet and average about 1 foot; partings of claystone and mudstone, commonly less than 1 foot thick, separate the layers. Fresh limestone ranges in color from light to

dark gray and some is brownish; weathered surfaces are very light gray to buff and are commonly stained yellow and orange.

The limestone is basically a carbonate rock of which 60 to 90 percent consists of minute calcite (calcium carbonate) particles and lesser amounts of dolomite (calcium-magnesium carbonate); at least 10 percent consists of clay minerals; and the remainder consists of minor amounts of relatively insoluble minerals such as quartz, feldspar, mica, pyrite, and carbonaceous fragments. Because of its relatively high clay mineral content, the limestone is classified as impure and described as being "silty" or "clayey" (Table 2). Layers of unusually silty or clayey limestone tend to decompose, or break down rapidly.

Color and compositional variations are not associated with any particular limestone unit in any part of the bedrock section with the exception of limestone units 6 and 11.

Limestone 6, the Waynesburg Limestone of Piper (1933), is 20 to 30 feet below the Waynesburg (Wb) coal bed. This limestone is characterized by a relatively high silica content; large, irregularly shaped nodules of dark-gray flint (or chert) are commonly found along the bedding planes, and chert and quartz particles are disseminated throughout the rock mass. As a result, some of this limestone has a granular appearance; it is very hard and resistant, and difficult to excavate.

Limestone 11, the Upper Washington Limestone of Piper (1933), is about midway between the Jollytown (Jt) coal bed and the Ten Mile (Tm) coal bed. This limestone is medium gray to dark gray, and weathered surfaces are commonly very light gray or almost white. The purity of this limestone, as measured by calcium carbonate content relative to magnesium carbonate, clay minerals, and other impurities, is considerably higher than any other limestone in the bedrock section.

Distribution

The generalized lithologic columns (Plates) show the vertical distribution of the major limestone units, and the areal, or lateral, distribution and thickness variations of each of these units are shown on the lithologic maps.

In general, the limestone units are more persistent and more consistent in thickness than are the sandstone units. However, thicknesses do vary; a limestone unit may be very thick in one area and thin or absent in another.

Limestone and Land Use

From the standpoint of land use, the two most significant intervals within the bedrock column are (1) the 130-foot interval from the Sewickley (S) coal bed up to the Uniontown (Ut) coal bed; and (2) the 220-foot interval from the Washington (W) coal bed up to the Ten Mile (Tm) coal bed.

Table 2. *Chemical analyses, in percent, of representative samples of limestone*

Sample No.	Limestone Unit	Field Location	SiO ₂	Al ₂ O ₃	MgO	CaO	Total S	Total Fe ₂ O ₃	Loss on ignition
1	Limestone 5	Near Washington, Pa. Washington West quadrangle	1.15	2.83	2.3	43.6	0.008	2.8	38.0
2	Limestone 4	Near Washington, Pa. Washington West quadrangle	3.08	4.30	13.3	19.5	0.005	3.8	29.5
3	Limestone 4	Near Ginger Hill, Pa. Hackett quadrangle	1.30	3.27	11.7	27.5	0.019	3.0	38.6

Sample No.	Rock Unit	Field Location	SiO ₂	Al ₂ O ₃	MgCo ₃	CaCo ₃	S	Fe ₂ O ₃	P	Insol. residue
4	Limestone 4	Near Cannonsburg, Pa. Cannonsburg quadrangle	*	3.523	20.621	48.823	0.203	3.625	.051	22.520
5	Limestone 11	Near Washington, Pa. Washington East quadrangle	*	2.929 (incl. Fe ₂ O ₃)	3.813	72.866	.155	(with Al ₂ O ₃)	.061	17.380
6	Limestone 6	Outcrop near Jefferson, Greene Co., Pa.	5.92	1.83	5.59	82.56	*	1.57	*	*

Sources of data (see References): Samples 1, 2, and 3, U.S. Geological Survey laboratories, Denver, Colo.; 4 and 5, Miller (1934, p. 666); 6, Miller (1934, p. 402).

* No data reported

The lower part of the 130-foot interval from the Sewickley (S) coal bed up to the Uniontown (Ut) coal bed is dominated by limestone 4, the Benwood Limestone of Piper (1933), which everywhere is 40 to 50 feet thick. The upper part of the interval commonly contains four limestone units, each 5 to 20 feet thick, alternating with units of conspicuously greenish sandstone, siltstone, and mudstone. The thickness of the Benwood Limestone covers about two 20-foot contour intervals on the lithologic maps and its outcrop pattern is, therefore, shown as a blue band, about two contours wide. The upper part of the 130-foot interval is shown as a blue line pattern, indicating that about half of this upper part is limestone.

The 220-foot interval from the Washington coal bed up to the Termer Mile coal bed contains three 20-foot limestone units, which are near the base, middle, and top of the interval. In areas where this interval of bedrock is present, the three limestone units within it are closely associated with landslides and contact springs.

Limestone 6 (the Waynesburg Limestone) is 20 feet thick in the northwestern part of the Hackett quadrangle, where it replaces most of sandstone F (the Uniontown Sandstone). Elsewhere limestone 6 is generally less than 5 feet thick but, regardless of thickness, it is everywhere a hard resistant rock unit that is difficult to excavate.

Locally, discontinuous limestone units are associated with the Waynesburg A (Wa) coal bed, and where they are present contact springs and small landslides may develop.

Limestone Uses

Abundant resources of limestone are exposed within the mapped area but because of its high content of silica, magnesium carbonate, and clay minerals the limestone is poorly suited to such uses as flux, portland cement, high-grade lime, and road metal. However, to these few original primary uses have been added thousands of chemical and industrial uses of lime (CaO) manufactured from limestone and dolomite. Lime is now regarded as a basic industrial chemical (U.S. Bureau of Mines, 1965, p. 524). Also, impurities in limestone that are drawbacks with regard to some uses may well be desirable with regard to others. For example, a high-silica dolomitic limestone in central Indiana has been used for the manufacture of rock wool (Ritchie, 1960, p. 599).

Of particular interest is the growing use of lime in water treatment such as softening and purification, and in treating wastes and sewage. Serious problems with water pollution and acid-mine water drainage exist now and will very likely increase in the future; perhaps some improved chemical process or method involving lime treatment will aid in resolving some of them.

Lime is a relatively inexpensive, perishable, bulk commodity, and proper transportation is costly; these factors discourage long-distance hauling. It would be well to keep in mind, then, that abundant resources of limestone exist within the area, close to where lime and other limestone products may be needed in the future.

Water-bearing Limestone

Limestone 4 and limestone 6 are both water-bearing (Piper, 1933, p. 148, 149), undoubtedly because of the presence of well-developed joints which create passageways within the rock. Limestone is a harder, more brittle rock than sandstone, and fractures in the limestone tend to be more open. Moreover, the solubility of limestone tends to widen the fractures, thereby additionally increasing the effective permeability.

COAL

Description

The most distinctive feature of coal is its black color. Thin layers of black coaly shale and black or dark shale, rich in carbonaceous material, are commonly associated with the coal layers, and the coal itself is commonly divided into "benches" which are separated by thin layers (or partings) of claystone. Such units of coal and associated rock types occur throughout the bedrock section; the units are generally less than 6 feet thick and are referred to as "coal beds" even though only minor amounts of coal may be present. In the field, the presence of a coal bed is often marked by a more or less conspicuous band of black material, visible in roadcuts, for example. The coal bed generally can be identified by name (see the generalized lithologic columns, Plates), because the thickness of coal, the number of coal benches present, and the succession and thickness of associated rock layers are characteristic features.

Coal is a brittle rock, and "cleating" is a conspicuous feature of all the coals in the mapped area. Cleats (or joints) are small closely spaced fractures that cut through the coal and cause it to break into blocks. The most notable feature of this cleating (or jointing) is that only one conjugate set of joints is apparent; the directions (or orientations) of this conjugate set ($N. 70^{\circ} W. \pm 5^{\circ}$ and $N. 20^{\circ} E. \pm 5^{\circ}$) are remarkably consistent in all coals throughout the mapped area. The $N. 70^{\circ} W.$ cleat is much better developed and in mining terms this is referred to as the "face cleat," or the direction along which the coal breaks evenly and cleanly. The $N. 20^{\circ} E.$ cleat, not as well developed, is referred to as the "butt cleat"; the coals tend to break less regularly along this direction.

The coals within the mapped area (and elsewhere in southwestern Pennsylvania) are "bituminous," in that they contain less than 86 percent carbon, and "high volatile," in that they contain more than 31 percent

volatile matter. These high-volatile bituminous coals may be described further as "A," "B," or "C" according to their Btu values, where "A" is 14,000 Btu or more, "B" is 13,000-14,000 Btu, and "C" is less than 13,000 (U.S. Bureau of Mines, 1960, p. 115).

Bituminous coal is a major commodity resource within the mapped area, however, only the Pittsburgh (P), Redstone (R), and Waynesburg (Wb) coal beds attain sufficient thickness and quality to be considered commercial at the present time.

The Pittsburgh coal is for the most part, of "high-volatile A" rank; the ash content is low (about 6 percent), and the sulfur content is generally less than 2 percent. The Redstone coal is mostly "high-volatile B"; the ash content is generally less than 10 percent, and the sulfur content is generally greater than 2 percent. The Waynesburg coal is "high-volatile C"; the ash content is generally greater than 15 percent, and the sulfur content is generally greater than 3 percent. Representative analyses of these coals are given in Table 3.

The Pittsburgh coal is a "coking coal"; when heated in a sealed oven, it produces a gray porous mass of fixed carbon (coke). In contrast, the Waynesburg coal is "noncoking"; when heated, it leaves a clear or powdery residue. Coke is required for smelting iron ore; both coking and noncoking coals may be used interchangeably as fuel for power plants, and noncoking coals are used for cement and tile manufacture.

Distribution

The vertical distribution of coal beds is shown in the generalized lithologic columns, and their areal (or lateral) distribution and thickness variations are shown on the lithologic maps. (Coded thickness values along the lines marking coal beds refer only to coal thicknesses; thicknesses of the associated rock layers, which in total make up the coal bed, are not included).

The Pittsburgh coal has been largely mined out in most of the Monongahela, California, and Ellsworth quadrangles, and it is now being mined extensively within the Hackett quadrangle. However, the term "mined out" does not mean that all the coal has been removed. Many pillars have been left because of mine safety and surface construction, and substantial areas have been left where, for technical reasons, the Pittsburgh coal was not mined.

The Redstone coal is highly variable in thickness. A 4- or 5-foot layer of coal at one locality may be represented by only a few stringers of coal at a locality less than a mile away. In areas where thick Redstone coal is at or near the surface it has already been substantially removed by strip mining. A considerable number of small underground mining operations have been started but most of them have been abandoned because of the extreme thickness variability encountered, or because of lack of market.

Table 3. *Analyses, in percent, of representative samples of various coals*

Sample No.	Coal	Location	Proximate ¹			Ultimate ²				Calorific value			
			M	V	FC	A	S	H	C	N	O	Cal.	Btu
1	Waynesburg	Mead Twp., Belmont Co., Ohio	3.51	37.68	41.94	16.87	3.59	4.70	63.18	1.25	10.41	6320	11,377
2		Sara Bank, Luzerne Twp., Fayette Co., Pa.	—	33.2	46.8	20.0	3.7	—	—	—	—	—	—
3		Guthrie mine, near Waynesburg, Greene Co., Pa.	3.4	32.8	46.7	17.1	2.4	4.9	65.4	1.4	8.8	6529	11,750
4	Redstone	Country bank, German Twp., Fayette Co., Pa.	3.2	33.8	55.1	7.9	2.6	—	—	—	—	7443	13,400
5		Redstone mine, near Hackett, Hackett quadrangle, Pa.	1.5	35.6	53.3	9.6	2.1	—	—	—	—	—	—
6	Pittsburgh	Marianna mine, near Ellsworth, Ellsworth quadrangle, Pa.	1.4	33.9	58.3	6.4	1.3	5.3	78.4	1.4	7.2	7883	14,190
7 ³		Catsburg mine, near Monongahela, Monongahela quadrangle, Pa.	2.8	32.5	57.3	6.4	1.1	5.4	77.2	1.3	8.6	7706	13,870

¹ Proximate: M = moisture; V = volatile matter; FC = fixed carbon; A = ash² Ultimate: S = sulfur; H = hydrogen; C = carbon; N = nitrogen; O = oxygen³ Composite of 5 samples⁴ Sources of data (see References): Sample 1, Denton (1960, p. 46); 2, Hickok and Moyer (1940, p. 390); 3, Fieldner, Cooper, and Osgood (1928, p. 88); 4, Hickok and Moyer (1940, p. 379); 5, 6, 7, Fieldner, Cooper, and Osgood (1928, p. 121).

The Waynesburg coal bed is at or near surface at many localities. In most places this coal is sufficiently thick to be commercial, but its high ash and sulfur content have limited its commercial value. In the past, the Waynesburg coal has been strip mined locally, and a very small amount of underground mining has been done, chiefly to obtain fuel for domestic use. However, no significant mining has been done or is currently in progress, and large volumes of Waynesburg coal still remain. Estimated resources of Waynesburg coal within the mapped area are given in Table 4. Additional information and resource data on coals in Washington County may be found in the U.S. Bureau of Mines Report of Investigations 5109 (Wallace and others, 1955).

The Waynesburg coal is a good marker bed. Characteristically, it occurs in two benches, of which the lower (main) bench is the thicker, better coal. However, in the central part of the mapped area, and particularly along the border area between the Hackett and Monongahela quadrangles this coal bed is commonly split by lenses of mudstone and siltstone which may be as thick as 15 feet. Where such splits occur a third bench of coal is usually present below the main bench. These splits occur unexpectedly, and the presence of the third bench of Waynesburg coal can create some confusion regarding which part of the bedrock section one is viewing. In such areas, the third bench is often referred to as the “false Waynesburg” coal. The relation of this third bench to the other Waynesburg coal benches is shown diagrammatically in the lithologic column.

Table 4. *Estimated resources of Waynesburg coal and Redstone coal (in millions of short tons)*

<i>Quadrangle</i>	<i>Measured</i>	<i>Indicated</i>	<i>Inferred</i>	<i>Total</i>
WAYNESBURG COAL				
Hackett	36.1	75.5	52.5	164.1
Ellsworth	45.3	160.9	—	206.2
California	22.2	7.1	—	29.3
Monongahela	18.1	12.7	—	30.8
<i>Total</i>	121.7	256.2	52.5	430.4
REDSTONE COAL				
Monongahela	40.9	34.4	—	75.3

Coal and Land Use

The underground mining of coal, its potential effect upon land uses, and the commercial value of the coal create economic problems and situations that are beyond the scope of this report. However, the effects of noncommercial surface coal beds upon certain types of land uses are perhaps equally important, and a few such effects are mentioned here.

Both the Pittsburgh and Waynesburg coal beds are commonly overlain by thick, massive units of channel-fill sandstone. At many localities the channels that these sandstone bodies occupy have been cut down to—and sometimes into—these underlying coal beds. In underground mining of the Pittsburgh coal many such channel-fill bodies of sandstone have been encountered unexpectedly, and where these sand bodies have effectively cut out some thickness of Pittsburgh coal they are referred to as “sandstone cutouts,” “wants,” or “faults”; it is usually technically impractical to recover the coal from beneath sandstone cutouts. The locations and outlines of these “cutout” areas are, of course, of vital concern to underground mining operations, and mine maps in general reflect their position and extent. However, these situations do make the ground surface areas directly above the cutouts more attractive for many land uses, because it is likely that the coal below will never be mined.

Throughout the bedrock section the many thin coals are associated with claystone, mudstone, black or carbonaceous shale, and underclay. These associated rocks are all relatively impermeable and as a result they create impervious layers within the bedrock section; joints cutting these soft plastic rocks are quickly sealed, and have little or no effect in increasing permeability. Consequently these impervious layers become zones along which contact springs may develop (on hillside slopes), and where coal beds intersect hillside slopes the areas or zones just below these intersections generally consist of saturated, unstable soil.

The effects of such impermeable layers, and resulting zones of saturated, unstable rock and soil upon existing county roads are often very apparent—particularly after a period of wet weather. Many of the roads that cross such areas require constant and considerable maintenance. In planning and constructing new roads, such problems can and should be anticipated and appropriate engineering precautions should be taken.

Coal Uses

Coal has long been a primary energy source, and the Pittsburgh coking coal has, of course, been a major factor in the tremendous industrial and economic growth of the Pittsburgh steel empire and in the economy of southwestern Pennsylvania. However, the national importance of coal as a primary source of energy was diminished by the advent of low-cost oil and gas, and coal has had a long history of decreasing demand and production.

But today much the same situation exists regarding the multitudinous uses of coal as it does with limestone. The largest and fastest growing market for coal is in power generation for the electrical utility industry (U.S. Bureau of Mines, 1965, p. 132). Recent research in converting coal to liquid and gaseous fuels indicates a promising future. Coal is widely

used for the production of such products as toluene, benzene, tar derivatives, and fertilizers (U.S. Bureau of Mines, 1965, p. 140); coal *ash* may be used in the manufacture of rock wool for insulation.

It is very likely that coal production has reached, and passed, its lowest point. Uses of coal are increasing, rather than decreasing, and the tremendous resources of Waynesburg coal that exist in the mapped area (Table 4) and elsewhere in southwestern Pennsylvania may soon be needed.

MUDSTONE

Description

The convenient term "mudstone" is herein applied to nondescript, heterogeneous, relatively thick (20-50 feet) masses of poorly sorted, poorly bedded, shaly rock. Units of rock that may also be called "shale" are included in the mudstone category.

Mudstone consists mainly of clay-size particles, but considerable amounts of silt- and sand-size particles are disseminated throughout the mass and are also concentrated in thin, rather sharply defined layers. Grains of quartz, mica, pyrite, and other heavy minerals are scattered throughout the mass. The mudstone is essentially a composite—and to a considerable extent, a mixture—of other rock types. Siltstone, a laminated rock in which silt-size particles predominate, is distributed throughout mudstone masses in the form of thin, sharply defined layers commonly less than 2 inches thick; sandstone layers up to 3 feet thick are also common, as are thinner, more irregular layers of limestone. Many mudstone layers are dark and are rich in carbonaceous material. Weathered mudstone masses (or units) are, in general, olive to greenish gray. In bulk, mudstone tends to be soft, plastic, impermeable, and cohesive. Joints cutting through mudstone are small and closely spaced, and are usually quickly sealed by the soft, plastic rock; consequently, joints in mudstone cause little or no increase in effective permeability. Cliffs do not form in mudstone units, although some of the more resistant layers may become etched out in steep exposures. Over most of the mapped area, slopes formed on mudstone are relatively gentle.

Distribution

Mudstone units make up the bulk of the bedrock section in the mapped area; no particular mudstone unit is especially notable. For these reasons, portions of the bedrock section that consist mainly of mudstone are left blank in the generalized lithologic columns, and areas underlain mainly by mudstone are left blank on the lithologic maps.

Limestone, sandstone, and siltstone layers within a mudstone mass commonly grade laterally into limestone and sandstone-siltstone units

and, conversely, mudstone units are lateral equivalents of limestone and sandstone-siltstone units. Mudstone units are perhaps most prevalent in the bedrock section from the Uniontown (Ut) coal bed up to the Washington (W) coal bed.

CLAYSTONE

Description

Claystone is a soft, plastic rock made up largely of clay-sized particles of clay minerals which in order of abundance are illite, chlorite, kaolinite, and mixed layer (illite-chlorite) clays; carbonate minerals and carbonaceous material are common impurities. The colors of both fresh and weathered claystone range from light gray to buff to dark gray, depending on the amounts and types of impurities present. Many claystone layers have a yellow-orange staining.

Claystone is commonly associated with limestone units and with coal beds. Directly beneath coal beds claystone is commonly referred to as "underclay." A notably thick layer of underclay is beneath the Waynesburg (Wb) coal bed.

Samples of claystone and underclay from widely scattered localities in the Ellsworth, Monongahela, and California quadrangles, and in adjacent quadrangles to the west, were collected and analyzed by the Pennsylvania Geological Survey. Results and potential uses are listed under "Washington County" in a recent mineral resources publication on the "Properties and Uses of Pennsylvania Shales and Clays" (O'Neill and others, 1965). Additional analytical data are included in Table 5.

Distribution

Claystone units 1 to 10 feet thick are scattered throughout the bedrock section, but in total they constitute a very small percent of the bedrock.

SOIL AND ALLUVIUM

SOIL

Within the mapped area, the soil cover is generally less than 5 feet thick. In most places, then, bedrock will be encountered less than 5 feet below the ground surface. The soils are "residual," in that they were derived mainly from the bedrock directly beneath them, and soil types are therefore closely related to rock types.

A comprehensive report on the soils of Washington County and their effects upon land use and land-use planning has recently been published (Weaver and others, 1966). The soil types present were mapped on aerial photographs. Copies of the aerial photograph soil survey maps

Table 5. *Data on Atterberg limits, plasticity index, PH, swell index, and potential volume change and rating for representative samples of mudstone, claystone, and landslide material**

Laboratory sample number	Type of sediment	Atterberg limits			Potential volume change (P.V.C.)	
		Liquid limit (L.L.)	Plastic limit (P.L.)	Plasticity index (L.L.-P.L.)	pH	Rating #
D-800294	Silty mudstone	27	24	3	7.51	2, marginal
D-800296	Mudstone	24	20	4	7.80	1.2, noncritical
D-800295	Claystone	30	20	10	7.70	2.4, marginal
D-800297	Claystone	33	24	9	7.50	2.5, marginal
D-800298	Landslide material	27	15	12	5.12	.3, noncritical
D-800299	Landslide material	36	26	10	4.61	1.1, noncritical

* Analysts: T. C. Nichols, G. S. Erickson, and J. C. Thomas, U.S. Geological Survey, Denver, Colo.

Rating according to specifications of Federal Housing Administration as contained in manual by Lambe (1960). Scale of rating: 0-2, noncritical; 2-4, marginal; 4-6, critical; 6-12, very critical

are on file in the County Planning Commission Office, Washington, Pa., and in the county office of the U.S. Department of Agriculture, Soil Conservation Service, Washington, Pa. These are available for reference.

ALLUVIUM

An unconsolidated mixture of silt, sand, gravel, and cobbles is mapped separately. On the lithologic maps, deposits of alluvium are shown in yellow and labeled "Qa." The Carmichaels Formation, also shown in yellow but labeled "Qc," consists of remnants of older alluvium deposited during the Ice Age, some 10,000 years ago, within a broad valley marking the pre-ice course of the present-day Monongahela River. Within the mapped area this pre-ice age valley is roughly coincident with the present Monongahela River valley. However, the elevation of the rock floor of the pre-ice age valley and associated drainage—which is also the elevation of the base of the Carmichaels Formation—is about 910 feet, or about 170 feet above the present level of the Monongahela River.

CONTACT SPRINGS

Contact springs are common throughout the mapped area. A *contact* is the surface along which a layer or unit of one type of rock rests upon, or makes contact with, a layer or unit of another type. These surfaces separating layers or units of different rock types, of course, extend into the ground just as the rock layers do. Where a unit of permeable rock rests on a unit or layer of impervious rock, water percolating down through the permeable layer is blocked at the upper surface of the impervious layer. The water tends to move sideways along the contact and where such a contact extends out to the ground surface, the water moving along it escapes as a *contact spring*. Hillsides are common localities for contact springs and where a favorable contact follows along a hillside for some distance there may be a line of springs all discharging water along the same contact surface. If the hillside is high enough to cut across several contacts between permeable and impervious rock units several lines of contact springs may occur along the same hillside.

Contact springs are significant both as sources of water and as indications of the levels at which water may be found. Many contact springs discharge water more or less continuously. Such supplies of water might be conserved in artificial stock ponds or small reservoirs placed just below the spring location. On the other hand, such sources of water can cause serious problems in connection with small coal-mining operations and with road or building construction; an artificial cut made into a hillside anywhere along a line of contact springs might release a flow, or seepage, of unwanted water.

The following brief discussions concern impervious layers, sandstone-coal bed contacts, limestone-coal bed contacts, miscellaneous contacts, and field recognition.

IMPERVIOUS LAYERS

Coal beds are very effective as impervious layers. The coal itself may have some degree of permeability due to cleating, but the associated layers of claystone, black or carbonaceous shale, and underclay are generally impervious. Coal beds are also very persistent, and many of them are overlain by thick units of sandstone or limestone; consequently most of the more prominent and prevalent lines of contact springs coincide with coal beds.

Rock types such as claystone, dark shaly limestone, and black or dark shale all tend to be impervious, but they commonly occur in layers that are too thin and too scattered to be effective in this respect. However, wherever layers of such rocks are concentrated in zones several feet or more thick, such zones can be impervious. For example, the uppermost part of the Benwood Limestone (limestone 4) consists mainly of claystone partings, dark shaly limestone, and black shale which in many places form an impervious layer. Contact springs are fairly common at this level.

SANDSTONE-COAL BED CONTACTS

The two most common and best developed lines of contact springs are marked by the Uniontown (Ut) and Waynesburg (Wb) coal beds. Both of these coal beds are commonly overlain by thick units of massive jointed sandstone, and these sandstone-coal bed contacts are at or near the ground surface in most of the mapped area.

Rain and melting snow percolating downward from the surface through permeable layers, and ground water moving within the layers are blocked by the impervious coal bed. The water tends to move laterally in the direction of the maximum dip of the impervious rock layer, and contact springs may occur along the line where the impervious rock layer intersects the slope of a hillside. Where the impervious layer extends through a ridge or a hill, contact springs are more pronounced on the down-dip side of the hill. The dips of rock layers within ridges or hills that span the axes of broad, gentle folds are, of course, very slight, but in southwestern Pennsylvania *all* of the folded rock layers have subsequently been tilted southwest, and in the axial areas of the major structures the amount of dip introduced by tilting may be greater than the amount of dip introduced by folding. Consequently, contact springs may occur along the crests of anticlines and artesian conditions may exist if the overlying, water-bearing bed rises to higher elevations toward the northeast. Relations of water-bearing beds and impervious layers to geologic structures in southwestern Pennsylvania are described in greater detail by Piper (1933, p. 35-36).

On the lithologic maps, the lines representing the Uniontown and Waynesburg coal beds are lines along which contact springs are common; they are also guidelines to where contact springs may appear in the future.

LIMESTONE-COAL BED CONTACTS

Contact springs occur along the contacts between coal beds and overlying thick units of jointed limestone; however, in general the springs are not as well developed or prevalent as the springs associated with the sandstone-coal bed contacts.

On the lithologic maps, lines marking the positions of the Sewickley (S), Waynesburg A (Wa), and Washington (W) coal beds are also lines along which contact springs may occur.

MISCELLANEOUS CONTACTS

Lines of incipient contact springs may occur along the base of sandstone D, along the top of limestone 4, and along the bases of the four limestone units in the interval between the top of limestone 4 and the base of the Uniontown (Ut) coal bed.

Lines of incipient contact springs are also common along both the top and the base of each of the three limestone units in the interval from the Washington (W) coal bed up to the Ten Mile (Tm) coal bed. In the western part of the Hackett and Ellsworth quadrangles, hillsides formed in the upper part of the bedrock section are relatively steep and many of them are high enough to cut across four or five lines of contact springs. These parts of the mapped area are where landslides are most common and it is very likely that this combination of lines of contact springs and steeper slopes is a major contributing cause of landsliding.

FIELD RECOGNITION

Many of the contact springs are, of course, obvious in the field. However, incipient contact springs, which are little more than a zone of water-saturated soil covering water-bearing rock, are not as conspicuous. Evidence of them is commonly expressed in the form of bands of greener, more rank vegetation along hillsides; these bands may be broken by creep, or plastic flow downhill, of moist, unstable soil. Recent soil creep or flows quite often leave rather prominent, bare scars on hillsides; older flows that have since been covered by grass and vegetation often appear as "hummocky" masses which contrast with the generally smooth surface of the slope. In this respect, evidence of an incipient contact spring is actually in the form of a landslide.

LANDSLIDES

Landslides, which occur throughout the area, are a common and continuing process and also a problem.

Adequate analyses of the causes, mechanics, complexities, and implications of landsliding are beyond the scope of this report. The purpose herein is to call attention to landsliding, describe it briefly, and mention some of the geologic conditions that are probably involved.

Although the term "landslide" has become associated with catastrophic movements of great masses of soil and bedrock, size is not a distinguishing feature. Any downward and outward movement of slope-forming materials—natural rock, soils, fill, or combinations—produces a landslide. A landslide that begins upslope from a house and causes severe damage to its foundation is not different in principle (or mechanically) from an unnoticed one that only leaves a hummocky scar on a slope in the pasture. Some amount of downhill soil-creep is to be expected, however, and there is no sharp dividing line between this process and landsliding. Again the difference is usually only a matter of degree or conspicuousness, with both resulting from the same geologic conditions.

On the lithologic maps, the small orange-colored areas labeled "Qls" represent known landslides. Undoubtedly many more have been overlooked and others have occurred since the maps were compiled. Very likely too, there are many localities where the matrix of soil and rock fragments is ready to slide, and it will do so as soon as some natural or artificial event triggers it. Several days of hard rain or the excavation of the toe of a dormant landslide might reactivate the slide.

Most of the landsliding in the area occurs along hillsides and in the steep headland areas of the drainage network. The matrix of soil and rock fragment begins creeping or flowing downhill. In the zones where such slides begin, some rotation or scalloping may occur later. This type of landslide may be described as "earthflow." Slides also occur along the walls of the steeper valleys, where massive blocks of sandstone and limestone break loose, slump downward, and rotate. This type may be described as "block-rotation slump." These descriptive terms follow the landslide classifications outlined in "Landslides and Engineering Practice" (Eckel, 1958, pl. 1. facing p. 40).

EARTHFLOW LANDSLIDES

Distribution

The lithologic maps show a close association between earthflow landslides and thick units of limestone. Earthflow landslides are most numerous on slopes formed in the 220-foot section of bedrock from the Washington (W) coal bed up to the Ten Mile (Tm) coal bed. Within the Hackett and Ellsworth quadrangles, limestone units associated with

the Waynesburg A (Wa) coal bed are also subject to sliding. In the localities within these quadrangles where this limestone is not shown and landslides are mapped, the landslide strongly suggests that some limestone is present. At localities where the bedrock section below the Uniontown (Ut) coal bed is considerably above drainage level, landslides also occur, particularly on slopes on the bedrock section from the base of limestone 4 (the Benwood Limestone) up to the base of the Uniontown (Ut) coal bed.

The largest and by far the greatest number of landslides are associated with the three prominent limestone units in the section between the Washington (W) coal bed and the Ten Mile (Tm) coal bed. The size of some of these landslides as mapped, however, may be somewhat deceptive. A small slide may originate within the upper limestone unit, coalesce downslope with another slide that originated within the middle limestone unit, and these two slides may in turn merge downslope with a third slide from the lower limestone unit. Consequently, although the area of sliding may appear to be extensive, three separate slides are actually involved.

BLOCK-ROTATION SLUMPS

Block-rotation slumps are generally limited to the areas along the walls of the steep valleys of the major tributaries to the Monongahela River. In this type of landslide, massive blocks of sandstone or limestone break loose, generally along characteristic curvatures of failure; many of the blocks rotate as they slump downslope and debris slides of smaller disoriented blocks may be associated with these block-rotation slumps.

Generally, block-rotation slumps occur within the part of the bedrock section that is below the top of limestone 4 (the Benwood Limestone). The bedrock consists mainly of massive sandstone and limestone layers (or units), alternating with relatively weak, incompetent mudstone units which may also contain varying amounts of coal, carbonaceous shale, claystone, and siltstone. The massive, more resistant sandstone and limestone layers tend to be undercut as the underlying weaker layers weather back. Joints and contact-spring conditions tend to accelerate this process. The faces of the resistant rock layers exposed along the valley walls tend to be vertical, and the layers may even overhang at many localities. Rock failure by gravity, along curvatures of failure, and perhaps by down-dip gravity sliding of massive blocks along the lubricated planes of contact springs, would be a natural consequence of these conditions.

It has been noted that the bedrock layers tend to bend upward somewhat as they approach intersection with the walls of major valleys such as the Monongahela River valley. The phenomenon is very likely a response to removal of rock overburden as the steep and rather wide

valleys developed. In essence, the bedrock seeks relief from the stresses it had previously been under. In most cases this upward bending is localized, and the resulting dips are contrary to regional structural attitudes. Since downcutting and incision of the drainage pattern is a relatively recent process (dating from the last ice age some 10,000 years ago) it may be assumed that upward bending is also relatively recent, and that the process accentuates the breakage patterns in the bedrock, perhaps leading to the characteristic curvatures of rock failure. These are only speculations. Much detailed study would be required before this upward bending could be counted or discounted as a factor in landslide development.

LANDSLIDES, LAND USE, AND LAND-USE PLANNING

Landslides destroy property, disrupt power and telephone lines, and block or sever roads; slides which occurred during the wet spring of 1967 provided ample new evidence of their destructive power.

Landslides will continue to affect present land use. In most places landslide prevention would be a difficult and impractical task, but a systematic, quantitative, statistical, engineering geology study of the geologic conditions involved in landslides and landsliding would be desirable. These geologic conditions include joints, limestone and limestone units, associated soil types, impervious layers, contact springs, and slope gradients (because of the association of earthflow landslides with slope gradients characteristically greater than 20 percent). Objectives of such an engineering geology study would include determining the geologic causes of landsliding, establishing methods of preventing reactivation of existing slides, locating areas or zones where landslides are most likely to occur in the future, and providing information on the type and extent of landsliding to be expected.

A forewarning of landslide probability would permit future land-use plans to be adjusted accordingly—before land is committed and construction begins.

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[illegible]

Mudstone

Thickness, with three beds of sandstone, sandstone, and coal

Coal

Thickness, with three beds of sandstone, sandstone, and coal

Artificial fill

Thickness, with three beds of sandstone, sandstone, and coal

Anticline

Showing position of main line. Disused where approximately located.

Syncline

Showing position of trough line. Disused where approximately located.

Structure contours

Drawn on the base of the Pittsburgh coal bed, dashed where projected from surface base. (Circle indicates strike and 10 feet, dash in a square and level).

Quality of surface data

1. measured section, more than 10 feet
2. measured section, less than 10 feet
3. contact exposed, incline present
4. contact dip, rock, washed and, or, sampled
5. position of bed or contact inferred from closely related to bed or fault
6. position of bed inferred from aerial data to known beds

Cored drill hole

Procedures to base of Monongahela Group

Abandoned quarry

Abandoned drift mine

Mine shaft

Abandoned mine shaft

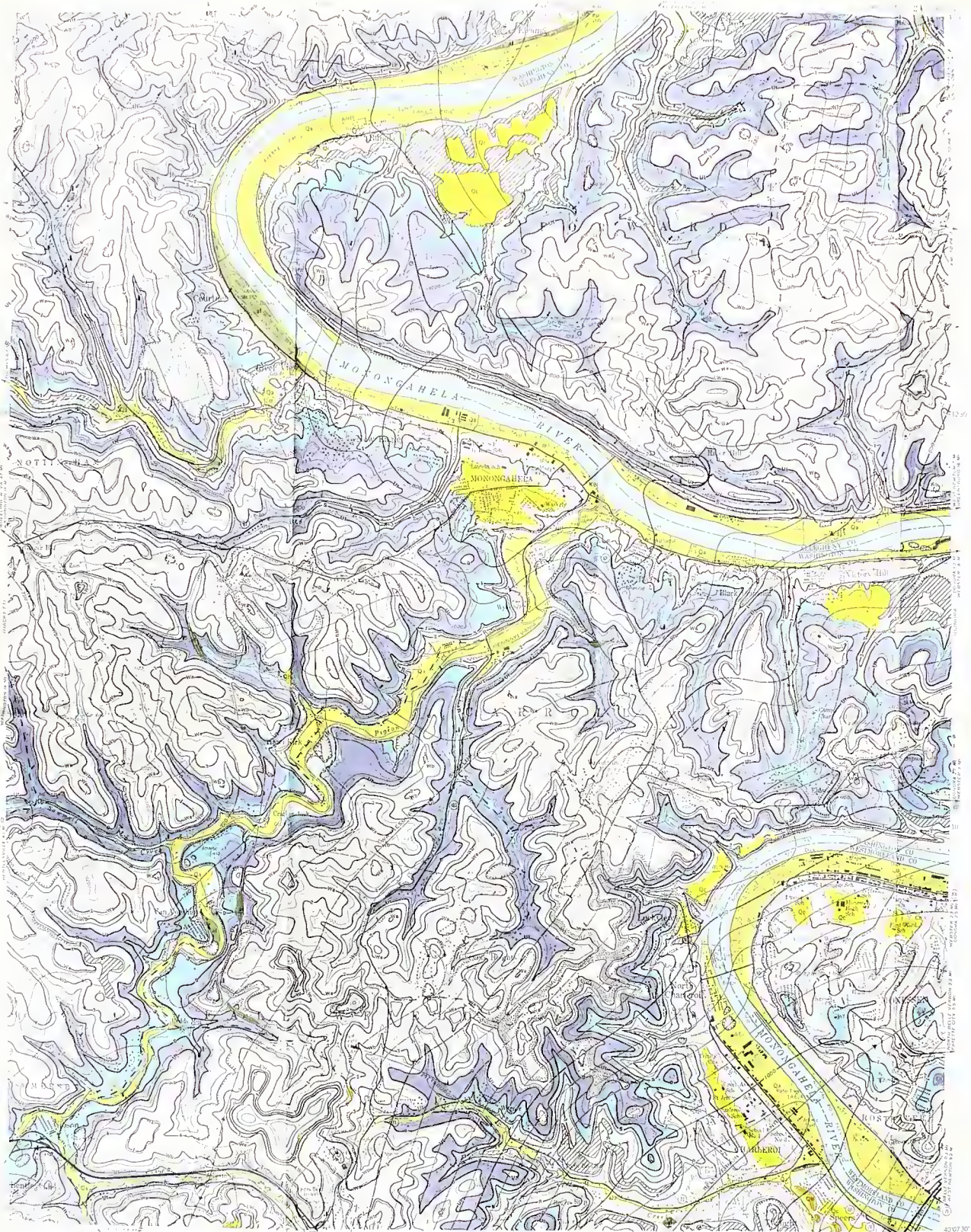
Open-cut (strip) mine

Mine dump



Geology mapped by B. H. Kent, USGS, 1963-64. Data for structure contours obtained in part from Consolidation Coal Co., (Baltimore) Mines Corp. and United States Steel Corp., and in part from coal mine maps on file with the Pennsylvania Dept. of Mines and Mineral Industries.

By
Bion H. Kent and Stanley P. Schweinfurth
1969



Base by U. S. Geological Survey, 1954

SCALE 1:24,000



Geology mapped by J. B. Roen, U.S.G.S. 8-11 June 1965, and J. B. Roen, U.S.G.S. 11-14 June 1965. Data for structure patterns in coal from Bituminous Area Corporation, Commercial Coal Company, and United States Steel Corporation.

LITHOLOGIC MAP OF THE MONONGAHELA QUADRANGLE, WASHINGTON AND FAYETTE COUNTIES, PENNSYLVANIA

By

John B. Roen, Ben H. Kent and Stanley P. Schweinfurth

1970



EXPLANATION



Limestone
a. Limestone, b. Limestone, c. Limestone
d. Limestone, e. Limestone, f. Limestone
g. Limestone, h. Limestone, i. Limestone
j. Limestone, k. Limestone, l. Limestone
m. Limestone, n. Limestone, o. Limestone
p. Limestone, q. Limestone, r. Limestone
s. Limestone, t. Limestone, u. Limestone
v. Limestone, w. Limestone, x. Limestone
y. Limestone, z. Limestone

Structure

Major, minor, and very minor, and very minor



Coal, showing thickness
a. Coal, b. Coal, c. Coal, d. Coal, e. Coal, f. Coal, g. Coal, h. Coal, i. Coal, j. Coal, k. Coal, l. Coal, m. Coal, n. Coal, o. Coal, p. Coal, q. Coal, r. Coal, s. Coal, t. Coal, u. Coal, v. Coal, w. Coal, x. Coal, y. Coal, z. Coal

Artificial fill

Artificial fill

Artificial fill
a. Artificial fill, b. Artificial fill, c. Artificial fill, d. Artificial fill, e. Artificial fill, f. Artificial fill, g. Artificial fill, h. Artificial fill, i. Artificial fill, j. Artificial fill, k. Artificial fill, l. Artificial fill, m. Artificial fill, n. Artificial fill, o. Artificial fill, p. Artificial fill, q. Artificial fill, r. Artificial fill, s. Artificial fill, t. Artificial fill, u. Artificial fill, v. Artificial fill, w. Artificial fill, x. Artificial fill, y. Artificial fill, z. Artificial fill

Syncline

Syncline
a. Syncline, b. Syncline, c. Syncline, d. Syncline, e. Syncline, f. Syncline, g. Syncline, h. Syncline, i. Syncline, j. Syncline, k. Syncline, l. Syncline, m. Syncline, n. Syncline, o. Syncline, p. Syncline, q. Syncline, r. Syncline, s. Syncline, t. Syncline, u. Syncline, v. Syncline, w. Syncline, x. Syncline, y. Syncline, z. Syncline

Structure contours

Structure contours
a. Structure contours, b. Structure contours, c. Structure contours, d. Structure contours, e. Structure contours, f. Structure contours, g. Structure contours, h. Structure contours, i. Structure contours, j. Structure contours, k. Structure contours, l. Structure contours, m. Structure contours, n. Structure contours, o. Structure contours, p. Structure contours, q. Structure contours, r. Structure contours, s. Structure contours, t. Structure contours, u. Structure contours, v. Structure contours, w. Structure contours, x. Structure contours, y. Structure contours, z. Structure contours

Quality of surface data

Quality of surface data
a. Quality of surface data, b. Quality of surface data, c. Quality of surface data, d. Quality of surface data, e. Quality of surface data, f. Quality of surface data, g. Quality of surface data, h. Quality of surface data, i. Quality of surface data, j. Quality of surface data, k. Quality of surface data, l. Quality of surface data, m. Quality of surface data, n. Quality of surface data, o. Quality of surface data, p. Quality of surface data, q. Quality of surface data, r. Quality of surface data, s. Quality of surface data, t. Quality of surface data, u. Quality of surface data, v. Quality of surface data, w. Quality of surface data, x. Quality of surface data, y. Quality of surface data, z. Quality of surface data

Cored drill hole

Cored drill hole
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Quarry

Quarry
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Abandoned drift mine

Abandoned drift mine
a. Abandoned drift mine, b. Abandoned drift mine, c. Abandoned drift mine, d. Abandoned drift mine, e. Abandoned drift mine, f. Abandoned drift mine, g. Abandoned drift mine, h. Abandoned drift mine, i. Abandoned drift mine, j. Abandoned drift mine, k. Abandoned drift mine, l. Abandoned drift mine, m. Abandoned drift mine, n. Abandoned drift mine, o. Abandoned drift mine, p. Abandoned drift mine, q. Abandoned drift mine, r. Abandoned drift mine, s. Abandoned drift mine, t. Abandoned drift mine, u. Abandoned drift mine, v. Abandoned drift mine, w. Abandoned drift mine, x. Abandoned drift mine, y. Abandoned drift mine, z. Abandoned drift mine

Mine shaft

Mine shaft
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Abandoned mine shaft

Abandoned mine shaft
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Adit

Adit
a. Adit, b. Adit, c. Adit, d. Adit, e. Adit, f. Adit, g. Adit, h. Adit, i. Adit, j. Adit, k. Adit, l. Adit, m. Adit, n. Adit, o. Adit, p. Adit, q. Adit, r. Adit, s. Adit, t. Adit, u. Adit, v. Adit, w. Adit, x. Adit, y. Adit, z. Adit

Open-cut (strip) mine

Open-cut (strip) mine
a. Open-cut (strip) mine, b. Open-cut (strip) mine, c. Open-cut (strip) mine, d. Open-cut (strip) mine, e. Open-cut (strip) mine, f. Open-cut (strip) mine, g. Open-cut (strip) mine, h. Open-cut (strip) mine, i. Open-cut (strip) mine, j. Open-cut (strip) mine, k. Open-cut (strip) mine, l. Open-cut (strip) mine, m. Open-cut (strip) mine, n. Open-cut (strip) mine, o. Open-cut (strip) mine, p. Open-cut (strip) mine, q. Open-cut (strip) mine, r. Open-cut (strip) mine, s. Open-cut (strip) mine, t. Open-cut (strip) mine, u. Open-cut (strip) mine, v. Open-cut (strip) mine, w. Open-cut (strip) mine, x. Open-cut (strip) mine, y. Open-cut (strip) mine, z. Open-cut (strip) mine

Mine dump

Mine dump
a. Mine dump, b. Mine dump, c. Mine dump, d. Mine dump, e. Mine dump, f. Mine dump, g. Mine dump, h. Mine dump, i. Mine dump, j. Mine dump, k. Mine dump, l. Mine dump, m. Mine dump, n. Mine dump, o. Mine dump, p. Mine dump, q. Mine dump, r. Mine dump, s. Mine dump, t. Mine dump, u. Mine dump, v. Mine dump, w. Mine dump, x. Mine dump, y. Mine dump, z. Mine dump

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